THE AMERICAN MINERALOGIST
JOURNAL OF THE MINERALOGICAL SOCIETY OF AMERICA
VOL. 14 MARCH, 1929 NO. 3

THE TEMPERATURES OF MAGMAS*

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INTRODUCTION

In the recent literature so much difference of opinion has been expressed as to the temperatures of magmas and even as to whether magmas of basaltic composition have higher or lower temperatures than do those of rhyolitic composition, that a connected attempt to reach as definite a conclusion as possible on the subject, seems highly desirable. Much good evidence, from field and laboratory petrology, from geophysics, and from physical chemistry is now available and some fairly definite conclusions seem possible. I have therefore selected as the subject of my address: *The Temperatures of Magmas.*

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* Presidential address presented at the ninth annual meeting of the *Mineralogical Society of America*, in joint session with the *Geological Society of America*, New York City, December 27, 1928.

RHYOLITIC MAGMAS HAVE LOWER TEMPERATURES THAN BASALTIC MAGMAS

Many economic geologists and some petrographers still adhere to the belief that rhyolitic magmas have higher temperatures than basaltic magmas. So far as I am aware, the only evidence for this is the fact that basaltic rocks on heating become fluid at lower temperatures than do rhyolitic rocks. However, a careful study of the evidence, mostly petrographic, shows conclusively that the opposite is true and we explain the apparent discrepancy as due to the water and other mineralizers which are in the rhyolitic magma but are not in the rhyolitic rock melted in an open crucible. It has long been known that an obsidian with considerable water becomes fluid before the blowpipe at a rather low temperature but on continued heating it loses its water and thereafter can be made liquid only at a much higher temperature.

Let us consider the crystallization on slow cooling of a magma intermediate in composition between a rhyolite and a basalt yielding a basalt porphyry, or a gabbro porphyry, containing more or less quartz and orthoclase. The study of thin sections of such rocks shows that, with few exceptions, the early crystals to form are calcic plagioclase and dark minerals and, as crystallization proceeds, the feldspar becomes progressively more sodic. The remaining liquid will become poorer and poorer in the material for calcic feldspar and dark minerals and richer in that for quartz, orthoclase, and sodic feldspar. It thus approaches a granodiorite in composition and at some stage reaches that composition. As cooling and crystallization continue plagioclase of intermediate composition and some dark mineral crystallize, finally leaving a liquid with a composition near that of a pegmatitic granite. There can be no doubt but that the original magma with the composition of basalt required a higher temperature to keep it liquid than did the material with the composition of a granodiorite and that the "granitic" material was liquid at a still lower temperature. A study of the whole series of rocks between rhyolite and basalt leads to the inevitable conclusion that rhyolite or granite crystallize at the lowest temperature of the group and that quartz latite or granodiorite, andesite or diorite, and basalt or gabbro crystallize at successively higher temperatures.

A study of the artificial systems similar to the igneous rocks leads to the same conclusion. In the system albite-anorthite-diopside,[1] mixtures rich in anorthite and diopside, which is approximately the composition of basalt, are liquid only at the higher temperatures and as the albite increases in amount and diopside and anorthite decrease, the temperatures of complete liquidity become lower. The mixture with the lowest temperature of liquidity, near 1090°, has approximately the composition; albite 97 per cent and diopside 3 per cent, which is near the composition of a soda syenite.

The theory of magmatic differentiation by crystallization, as advocated by Bowen requires the primary basalt to be the high temperature magma, and, as cooling progresses, crystallization proceeds, followed by separation of the liquid and crystal parts, the liquid part possessing a progressively lower temperature. Hence, the temperatures of magmas are progressively lower from basalt toward rhyolite. Following Bowen, magmas of the alkaline rocks would have still lower temperatures.

The evidence offered by the thermal metamorphism of included fragments or of the wall rock indicates that gabbros have higher temperatures than granites.[2] On the other hand, Lacroix[3] concluded from his classical studies of inclusions that the trachytic rocks, including the related alkaline rocks, had higher temperatures than the basaltic rocks.

SUPERHEAT

Bowen[4] has discussed the problem of superheat and concluded that magmas in general have little superheat. The field and laboratory study of igneous rocks shows that, at least for most lavas and most small intrusions at the time of eruption or intrusion with their intratelluric crystals, this must be true. For larger intrusions, at the time of final emplacement, it must also be true.

If the various rocks are formed through crystal differentiation, the primary basalts might have much superheat but not the later, derived rocks, and this would be true whether differentiation took place through crystallization or assimilation. Locally the magma in the throat of a volcano may be excessively hot due to gas reactions, surface oxidation, etc.

[1] Bowen, N. L.; *Am. J. Sc.*, **XI**, 161–185, 1915.

[2] Schwartz, G. M.; *Journ. Geol.*, **XXXII**, 89–138, 1924.

[3] Lacroix, A.; *Les Enclaves des Roches Volcaniques*, 594, 1893.

[4] Bowen, N. L.; *Jour. Geol.*, **XXX**, 520–3, 1922.
Daly, R. A.; *Igneous Rocks and Their Origin*, p. 210, 1914.

TEMPERATURES OF LAVAS

General Statement[5]

At first, only lavas and near surface magmas will be considered so as to avoid the complications due to pressure. In a later section the modifications required for deep seated magmas will be discussed.

The kind of evidence we can hope to get to determine the temperatures of magmas are:

Direct measurements of flowing lava or of lava lakes.

The melting or inversion temperatures of minerals crystallized from a magma.

The melting or inversion temperatures of minerals included in a magma.

The melting temperatures of mineral aggregates.

The temperature at which a mineral breaks down, a solid solution unmixes, or a reaction takes place.

The effect of the magma on the wall rock or on inclusions.

A study of gas and liquid inclusions.

The temperatures at which rocks melt in the laboratory.

The temperature at which a mixture of the composition of the magma, including mineralizers, melts in the laboratory.

Any point, such as a eutectic on a phase rule diagram.

Direct Measurements

A number of direct measurements of the temperatures of basaltic magmas have been made, chiefly in the lava lakes of active volcanoes, but no such measurements have been made on rhyolitic lavas, as no volcano of such lavas is known to maintain a lava lake or otherwise offer opportunity for measurement of the temperature of the lava. However, should eruptions take place, such as those that formed the broad, low rhyolitic domes of the San Juan Mountains of Colorado, with their wide-spread, thin flows, no doubt quietly erupted; temperature measurements might be made.

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[5] Königsberger, J.; *N. Jb. f. Min., B.B.*, 32, 101–103, 1911.

Bowen, N. L. In Fairbanks, E. E.; *The Laboratory Investigation of Ores*, 172–199, 1928.

Harker, A.; *Natural History of Igneous Rocks*, 184–189, 1909.

Daly, R. A.; *Loc cit.*, 375–6.

Von Wolff, F.; *Der Vulkanismus.* Band 1, 34–43, 1914.

Shands, S. J.; *Eruptive Rocks*, 50–56, 1924.

Erdmannsdörffer, O H ; *Grundlagen der Petrographie*, 6–8, 1924.

Older measurements of the surface temperatures of Stromboli, Aetna, and Vesuvius lavas indicate temperatures of about 1000° to 1100° and those for Kilauea about 1200°. For the lavas of Vesuvius, Perret[6] records temperatures from 1000° to over 1200°.

In 1911, Perret[7] found the temperature of the lava lake at Kilauea, 30 to 50 centimeters below the surface, to be 1050°.

More recently, Jaggar, by forcing iron pipes containing Saeger cones into the lake, found the temperature of the lava to vary with depth. At the surface it was about 1000°, a meter below the surface the temperature decreased to 900°; it then increased to 1170° at the bottom of the lake which was 13 meters below the surface. He considered the high temperature at the surface to be due to surface reactions and that near the bottom to be due to oxidation caused by sinking blocks. He surmised that the temperature of the rising conduit lava was lower than that in the lower part of the lava lake. Individual measurements were as low as 750°.[8]

The temperature of the magma in the lava lake of Kilauea varies as much as 400° depending on depth, escape of gases, and surface reactions, and measurements at Vesuvius vary nearly as much. This is probably also true at other valcanoes and hence surface temperature measurements, as yet, give little data as to the temperature of the magma below the influence of surface agencies. Jaggar's observations show, however, that a basaltic magma may be relatively fluid at temperatures between 750° and 850°.

MELTING TEMPERATURES OF MINERALS

Only a few of the common rock-forming minerals melt within the range of magmatic temperatures and the data offered by melting phenomenon are otherwise indefinite. It can be stated with assurance, that when a mineral crystallizes from a solution the temperature must be below the melting point of the mineral. Thus orthoclase, which melts at about 1170° cannot form above that temperature. It may and probably commonly does crystallize much below that temperature. Likewise albite cannot crystallize above 1100°, nor aegirite above about 950°.

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[6] Perret, R. A.; The Vesuvius Eruption of 1906, *Carnegie Inst.*, **1924**, pp. 19, 120, 132.

[7] Perret, R. A.; *Am. J. Sc.*, **36**, 480, 1913.

[8] Jaggar, T. A.; *Jour. Wash. Acad. Sc.*, **VII**, 397–405, 1917; *Am. J. Sc.*, 44, 214, 1917.

It must be remembered that most of the rock minerals are solid solutions and the melting phenomenon are somewhat complicated and the melting temperatures differ with the composition.

The melting of an inclusion of a mineral in a magma would, if it took place without reaction so that the resulting liquid had the same composition as the crystal, require a temperature at least as high as the melting temperature of the mineral. However, the melting of orthoclase, quartz, and other inclusions, described in the literature is no doubt mostly due to a reaction between adjacent minerals, between the mineral and a liquid phase, or between the mineral and mineralizers. Such melting can take place at a temperature much below the melting temperature of the mineral.

Melting Intervals of Rocks

On cooling, a rock crystallizes over a temperature interval as is well recognized by our statement of the order of crystallization. In general, the groundmass is the last part to crystallize, and it may and probably does crystallize at a temperature much below the melting temperature of any of the minerals that are in it. This would be true for a dry melt and the mineralizers in the rock no doubt lower the temperature of crystallization still more. Basalt melts at about 984° to 1260° and granite at about 1215° to 1260°.

Because of the mineralizers in the magma, the temperature interval over which it crystallizes will be lower than that over which the rock can be melted in an open crucible in the laboratory.

Inversion Temperatures of Minerals

The inversion temperatures of minerals offer some of the best points on a geologic thermometer, since, where the composition of the crystalline phase does not vary, as in the forms of silica, this temperature is independent of the composition of the liquid phase. Where the crystalline phase forms solid solutions with some of the other constituents, as happens with wollastonite and pseudowollastonite which carry more or less $MgSiO_3$ in solid solution, the temperature of inversion depends on the composition of the crystalline phase.

The various forms of silica give us the best evidence as to the temperatures of magmas. Silica is known in seven crystalline modifications. Three of these are unstable and form only at low temperatures, four have ranges of stability near or within the temperatures of magmas. Low quartz is stable up to 573°, high quartz from 573° to 870°, tridymite from 870° to 1470°, cristobalite from 1470° to 1720°, and glass at a higher temperature.[9]

The inversion from low to high quartz is instantaneous in either direction and all quartz is low quartz below 573° and high quartz above 573°. The quartz-tridymite inversion is also enantiotropic but the rate of inversion at or near the inversion temperature of 870° is very slow and even with a flux, above 870°, quartz first inverts to the unstable form, cristobalite.

Remembering that no case is known in which a form crystallizes from a melt or solution at a temperature above its range of stability but that commonly a form crystallizes at a temperature below its range of stability, we can gain much information as to temperature conditions in magmas from which silica has crystallized. Quartz can crystallize, at atmospheric pressure, only at temperatures under 870°. High quartz will form above 573° but will invert instantly to low quartz on cooling below 573°. Low quartz will form below 573°. Tridymite can form at any temperature below 1470°, and cristobalite can form at any temperature below its melting point at 1720°. In laboratory experiments cristobalite commonly forms before tridymite in the stability range of tridymite.

With a flux, below 870°, tridymite forms before quartz and is recrystallized as quartz slowly. Although for a time when quartz was crystallizing from a magma at atmospheric pressure, the temperature must have been below 870°, should quartz be found that had crystallized from the magma as tridymite or cristobalite and inverted to quartz in the solid state, the crystallization from the magma might have taken place either above or below 870°. Moreover, quartz inclusions in a magma may not be converted to tridymite or cristobalite even though heated for a long time at a temperature considerably above 870°.

On the other hand, the presence of tridymite or cristobalite in a rock gives no indication of the temperature of crystallization as these forms can, and commonly do, form below 870°. In nature, tridymite and cristobalite are common minerals and are formed chiefly in the gas cavities or groundmass of volcanic rocks and many rocks with these minerals carry quartz phenocrysts. The conclusion seems inevitable that the tridymite and cristobalite formed at temperatures below, and probably considerably below 870°.[10]

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[9] Fenner, C. N.; *Am. J. Sc.*, **XXXVI**, 331–384, 1913.
Sosman, R. B.; *The Properties of Silica*, 782–6, 1927.

The application of these data to lavas leads to some important conclusions. Quartz phenocrysts are among the first constituents to crystallize from many rhyolites, quartz latites, and dacites and from some andesites and basalts. The conclusion seems justified that the rhyolites, quartz latites and dacites crystallize at temperatures below 870° and at least some andesites and basalts crystallize below that temperature also.

A magma of a given composition on cooling must crystallize according to a definite law. But the unknown quantity of mineralizers introduces an uncertainty as to the composition of the magma. For the basalts the variation in nature due to mineralizers is probably not very great and the temperature of crystallization does not vary much. The conclusion seems justified that some and probably most basaltic magmas remain almost completely liquid at temperature below 870°. Since the quartz phenocrysts are mostly intratelluric, they may have crystallized under considerable pressure and a correction—estimated as about 100° for 1000 atmosphere or 2 1/2 miles of cover,[11] must be added to 870°.

The inversion of low-high quartz at 573° gives another important point on the geological thermometer. This inversion takes place very rapidly and all the quartz we see is low quartz but some has been high quartz and has inverted on cooling below 573° to low quartz. Under favorable conditions, it is possible to tell with some assurance that the quartz of a particular occurrence crystallized as, or has at one time been, high quartz.[12]

A study of quartz from a large number of occurrences shows that the quartz phenocrysts of rhyolitic rocks and the quartz of granitic rocks crystallized as high quartz. In the pegmatites the quartz that crystallized directly from the magma as graphic granite crystallized as high quartz, while that deposited from hydrothermal solutions formed as low quartz.[13] Since the formation of the pegmatites is a continuous process it might be possible under favorable conditions, to determine at just what stage in the history of the pegmatites the temperature was about 573°.

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[10] Emmons, W. H. and Larsen, E. S.; Geology and Ore Deposits of the Creede District, Colo., *U.S.G.S. Bull.* **718**, 47–49, 1923.
Rogers, A. H.; *Am. Min.*, **13**, 73–92, 1928.

[11] Bowen, N. L.; *Loc. cit.*, p. 181.

[12] Wright, F. E. and Larsen, E. S.; *Am. J. Sc.*, **27**, 421–447, 1909.
Mügge, O.; *Neues Jb., Festband*, 181–196, **1907.**
Cent. f. Min., 609–15, **1921.**

Mügge[14] has shown that the prismatic quartz in a lava druse from Glade Creek, Wyoming, was formed above 573°.

The conclusion seems to be justified that rhyolitic and granitic magmas and pegmatites crystallize at temperatures above 573°, but that pegmatites do not form much above that temperature.

TEMPERATURES AT WHICH MINERALS BREAK DOWN OR SOLID SOLUTIONS UNMIX

The temperature at which soda-potash-feldspar unmix to form microperthite might be helpful if we had sufficient data but this temperature would vary with the composition of the solid solution.

Kozu, Yoshiki, and Kani[15] found that common hornblende from six localities, on heating in nitrogen gas, changed to brown, basaltic hornblende at about 750°.

Kozu and Yoshiki[16] found that brown hornblende dissociated at about 1050° and concluded that the hornblende, in inclusions must not have been heated above 1050°. Such hornblende could not have crystallized from a magma above 1050°.

THE EFFECT ON INCLUSIONS

The detailed studies of Lacroix and others[17] on inclusions in basaltic rocks have shown that shales and slates are commonly more or less melted, biotite is usually melted, orthoclase less commonly, and even quartz in some rocks. Granite or arkose inclusions may show some melting, especially at the contacts of the quartz and orthoclase, and Lacroix and Richarz have described granite melted to a vesicular glass.

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[13] Bastin, E. S.; *Geology of the Pegmatites and Associated Rocks of Maine, U.S.G.S. Bull.*, **445**, 36–39, 1911.

[14] Mügge, O.; *Cent. f. Min.*, 593–4, **1922.**

[15] Kozu, S., Yoshiki, B., and Kani, K.; *Science Reports, Tohoku Imp. Univ.*, Ser. III, Vol. **III**, 143–159, 1927.

[16] Kozu, S. and Yoshiki, B.; *Sci. Reports, Tohoku Imp. Univ.*, Ser. III, Vol. **III**, 107–117, 1927.

[17] Lacroix, A.; *Les Enclaves des Roches Volcaniques*, **1893.**
Thomas, H.; *Quart. Jour. Geol. Soc.*, **78**, 230–254, 1922.
Erdmannsdörffer, O. H.; *Fort. der Min.*, **5**, 173–209, 1916.
Richarz, Stephen; *Jour. Geol.*, **32**, 685–9, 1924.
Brouwer, H. A.; *Cent. f Min.*, 41–46, **1918.**
Ramdohr, Paul; *Cent. f. Min.*, 33–36, **1920.**
Collins, W. H.; The Geology of the Gowganda Mining Division, *Canada Geol. Surv., Mem.* **33**, 78, 1913.

Before applying these facts we must distinguish clearly between simple fusion, in which the liquid has the same composition as the crystals, and melting by reaction between adjacent minerals or between a mineral and a liquid or gas, in which case the liquid has a different composition from the crystals. For the partly melted quartz inclusions in basalt the liquid is in some cases reported as having minute crystals of sillimanite and other minerals showing clearly that it is not pure SiO_2. Furthermore, Fenner states, "finely ground quartz heated 108 hours at 1250°, showed only a small percentage of inversion (to cristobalite). After 90 hours at 1360° the product consisted of about two-thirds cristobalite and one-third unchanged quartz. At 1570° the reaction is nearly complete in an hour."[18] Silica glass inverts still more rapidly and at lower temperatures. It would seem certain that a fragment of quartz imbedded in a magma and protected from reaction at about 1600°, near its melting point, might be partly or completely fused but before cooling both the quartz and the glass would be converted to cristobalite or possibly further to tridymite. It is possible that below 870° quartz would again be formed but it should show clear indications of the inversion which would have taken place in the solid state and involves a large decrease in volume. I know of no well established case in which tridymite or cristobalite has formed at a high temperature and been inverted to quartz on cooling without a flux. Both minerals persist when once formed as the rates of inversion at temperatures near 870° without a flux are nearly zero.

It therefore seems certain that inclusions of quartz that are partly melted to glass, have melted by reaction and that the temperature must have been much below the melting temperature of quartz. Moreover, it seems probable that the magma should act as a flux on included quartz grains and that, if the temperature was much above 870°, the quartz would be either dissolved or inverted to tridymite.

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[18] Fenner, C. N.; *Am. J. Sc.*, **36**, 359, 1913.

The melting of orthoclase and other minerals is probably also largely by reaction.

Biotite melts or decomposes within the range of the temperatures of magmas. Lacroix states that biotite is commonly melted, and melted or decomposed biotite has been described by Richarz, Ramdohr, Goldschmidt, and others. Unaltered biotite is also common in igneous rocks as an early mineral to crystallize and in inclusions. Biotite may, therefore, be expected to yield important data on the temperatures of magmas. Day and Allen[19] found that the biotite of a dense glassy andesite from Lassen Peak when heated in a neutral atmosphere, persisted fairly well at 850°, but with further rise in temperature it showed increasing decomposition. They concluded that "this lava could not have been heated above 850° at any time after it approached the surface."

Inclusions of granite and arkose in many cases show no fusion but in others they are more or less fused. Sosman and Merwin[20] found that an arkose inclusion in Palisade diabase showed no fusion. As this arkose was half fused after heating in the laboratory at 1150° they concluded that the temperature of the diabase was under 1150°. From the partial fusion of granite inclusion Knopf[21] concluded that a basalt in Inyo County, California, had a temperature of 1025° if no water was present but with water was much lower.

Rarely quartz inclusions are associated with tridymite or cristobalite. For inclusions in basalt Lacroix[22] found tridymite and cristobalite always associated with gas cavities and he concluded that they required mineralizers for their formation. Brouwer[23] has described similar associations from Sumatra, Ramdohr[24] from Germany, and Thomas[25] from the Isle of Mull. They resemble the tridymite and cristobalite in the gas cavities of lavas which were crystallized as unstable forms below 870°.

[19] Day, A. L. and Allen, E. T.; *The Volcanic Activity and Hot Springs of Lassen Peak*, p. 49, 1925.

[20] Sosman, R. W. and Merwin, H. E.; *J. Wash. Acad. Sc.*, **3**, 389–395, 1913.

[21] Knopf, Adolph; A Geologic Reconnaissance of the Inyo Range and the Eastern Slope of the Southern Sierra Nevada, California, *U S.G.S.*, **75**, p. 110, 1918.

[22] *Loc. cit.*, pp. 520–1.

[23] *Loc. cit.*, p. 44.

[24] *Loc. cit.*

[25] *Loc. cit.*, pp. 239–240.

Lacroix[26] found quartz inclusions in trachytic rocks more often transformed to tridymite or cristobalite than in basaltic rocks and in one rock it was inverted to a mass of tridymite much like that produced artificially by heating quartz. For this inversion the temperature must have been above 870° and probably much above. In other rocks quartz remnants are surrounded by tridymite with some interstitial glass. Lacroix concluded that the temperatures of trachytic rocks were higher than those of basaltic rocks.

Lacroix[27] has shown that interstitial quartz in lavas may result from the inversion of original tridymite. Geijer[28] concluded that reticulated quartz is derived from the inversion of tridymite. Hawkes[29] has described quartz paramorphs after tridymite from Iceland; and Rogers[30] from California. Thomas[31] described tridymite in inclusions in basalt from the Isle of Mull that have reverted to quartz. Lacroix[32] described tridymite in cavities in an inclusion from Vesuvius that is partly inverted to quartz. In any of these cases the tridymite might have formed as an unstable form below 870°. The evidence for the inversion of tridymite to quartz without a flux must be very strong before we accept it, as the rate of inversion without a flux is near zero and it has not been possible to bring it about in the laboratory.

Wollastonite is stable at atmospheric pressure only below 1180° and above that pseudowollastonite is the stable form. The presence of MgO will raise this inversion temperature. Inclusions of limestone with wollastonite are rather common at igneous contacts, yet pseudowollastonite has never been found in nature. The conclusion seems justified that temperatures above 1180° are exceptional.

Goldschmidt[33] has constructed a temperature pressure diagram for the reaction $SiO_2 + CaCO_3 \rightleftarrows CaSiO_3 + CO_2$ but the accuracy of the curve has been questioned by Boydell[34] and Bowen[35]. Moreover, in the application of this curve to the metamorphism of a limestone, the effective pressure need have little relation to the weight of the load of rock as the carbon dioxide is able to escape and it seems probable that the rate of the reaction depends partly on the rate of escape of the CO_2.

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[26] *Loc. cit.*, p. 600.

[27] Lacroix, A.; *Le Montagne Pélce après sés Eruptions*, 52–58 **1908.**

[28] Geijer, Per; *Geol. Fören Förhandl.*, **XXXIV**, 1 pp. 51–80 1913.

[29] Hawkes, Leonard; *Geol. Mag.* **3**, 205–208, 1916.

[30] Rogers, A. F.; *Am. Mineral.*, **13**, 85, 1928.

[31] *Loc. cit.*, pp. 239–240.

[32] Lacroix, A.; *Bull. Soc. Min. France*, **31**, 334–8, 1908.

[33] Goldschmidt, V. M.; Die Gesetze der Gesteinsmetamorphose, *Vid. Skr. Math.-naturv. Klasse*, No. **22**, 1912.

Under a pressure of one atmosphere calcite breaks down to CaO and CO_2 at a temperature of 910°. The temperature of decomposition increases rapidly with pressure and is 1100° at a pressure of 20 atmosphere. This reaction may, for some inclusions, give a clue to the temperature of the magmas.

Fluid Inclusions

Estimations of the temperatures of magmas by measuring liquid and gaseous inclusions have as yet yielded no satisfactory data.[36]

TEMPERATURES OF DEEP SEATED MAGMAS

The deep seated magmas, which consolidated to form the great batholithic masses exposed to our view by erosion, at the time they reached their final position of consolidation, probably had about the same temperatures as the near surface magmas of the same composition. The effect of pressure should be to raise the temperature of crystallization but a greater content of mineralizers would tend to lower it. Some of the very deep magmas and in particular the primary basalt might have a much higher temperature. Indeed, the temperatures of plateau basalts may be much higher.

Most of the points on the geologic thermometer would have to be corrected for pressures. For the inversion low quartz–high quartz, the temperature of inversion is raised to 644° at a depth of ten kilometers.[37] For the inversion quartz-tridymite, Bowen calculated the increase in inversion temperature about 100° for a depth of four kilometers.

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[34] Boydell, H. C.; Operative Causes in Ore Deposition, *Institution of Mining and Metallurgy, London,* 16–22, 1927.

[35] *Loc. cit.*, pp. 190–1.

[36] Sorby, H. C.; *Quart. Jour. Geol. Soc.,* **XIV,** 453–500, 1858.
Nacken, O.; *Cent. f. Min.,* 10–20 and 35–43, **1921.**
Bowen, N. L.; *Loc. cit.*, pp. 192–3.

[37] Gibson, R. E.; *Jour, Phys. Chem.,* **32,** 1197–1205, 1928.

CONCLUSION

Let us assemble the evidence as to the temperatures of magmas.

1. Rhyolitic magmas have lower temperatures than basaltic magmas.

2. Direct measurements of temperatures at volcanoes give less satisfactory data than might be expected. Measurements of the basaltic magmas at Kilauea vary from 750° to over 1200°, those at Vesuvius vary nearly as much.

3. The melting temperatures of minerals that have crystallized from a magma yield only *maximum temperatures*. Some biotites must form below 850°.

4. The inversion temperatures of silica show that some basalts and most rhyolites and quartz latites are nearly completely liquid at temperatures below 870° and probably all magmas crystallize above 573°.

5. Common hornblende inverts to basaltic hornblende at a temperature of 750°. Hence most hornblende rhyolites and quartz latites, and many andesites crystallize below that temperature.

6. Since the inversion of quartz inclusions to tridymite or cristobalite is very rare, and this inversion takes place without a flux at an appreciable rate at 1250°, very few magmas have so high a temperature.

7. The lack of fusion of most granitic and arkose inclusions indicates a temperature below about 1150° but partial or complete fusion might take place at a much lower temperature in the presence of mineralizers—even the mineralizers in the crystallized granite or arkose.

The conclusions seem to be justified that some basaltic magmas have temperatures below 870°, many are below 1000°, very few are as high as 1260°, and probably most are not far from 800° to 900°. Rhyolitic magmas have lower temperatures. All are above 573° and below 870°. Nearly all are below the temperature of decomposition of biotite, about 850°, and that of common hornblende, about 750°. Probably most rhyolitic magmas have temperatures in the neighborhood of 600° to 700°.

PROCEEDINGS OF THE NINTH ANNUAL MEETING OF THE MINERALOGICAL SOCIETY OF AMERICA AT NEW YORK CITY

FRANK R. VAN HORN, *Secretary.*

The Mineralogical Society of America held its ninth annual meeting on December 27, 28, and 29, 1928, in conjunction with the Geological Society of America and the American Association for the Advancement of Science, at New York City, as guests of the American Museum of Natural History and Columbia University. On Thursday December 27, at 2:00 P.M., President E. S. Larsen called the regular annual meeting to order in the New York Academy Room of the American Museum of Natural History. On motion of the Secretary the reading of the minutes of the last annual meeting was dispensed with, in view of the fact that they had been printed on pages 105–117 of Volume 13 (Number 3) of THE AMERICAN MINERALOGIST.

ELECTION OF OFFICERS AND FELLOWS FOR 1929

The Secretary announced that 152 ballots had been cast unanimously for the officers as nominated by the Council. For fellows there was a unanimous vote of 69 ballots in the affirmative. All officers and fellows were declared elected.

The officers elected for 1929 are the following:

President: Arthur L. Parsons, Toronto University, Toronto, Canada.

Vice-President: Edward Wigglesworth, Boston Society of Natural History, Boston, Massachusetts.

Secretary: Frank R. Van Horn, Case School of Applied Science, Cleveland, Ohio.

Treasurer: Alexander H. Phillips, Princeton University, Princeton, New Jersey.

Editor: Walter F. Hunt, University of Michigan, Ann Arbor, Michigan.

Councilor, 1929–1932: Clarence S. Ross, United States Geological Survey, Washington, D. C.

The fellows elected follow:

Martin J. Buerger, Massachusetts Institute of Technology, Cambridge, Massachusetts.

John W. Gruner, University of Minnesota, Minneapolis, Minnesota.

Walter H. Newhouse, Massachusetts Institute of Technology, Cambridge, Massachusetts.

The Secretary also announced that the Council by virtue of authority given it by the Constitution had elected the following Honorary Life Fellows:

Professor Friedrich J. Becke, University of Vienna, Austria.

Professor Reinhard Brauns, University of Bonn, Germany.

Professor Waldemar C. Brögger, University of Oslo, Norway.

Professor Friedrich Rinne, University of Leipzig, Germany.

REPORT OF THE SECRETARY FOR 1928

To the Council of the Mineralogical Society of America: The Secretary herewith begs to report that the roll of the Society now comprises 105 fellows and 235 members in good standing. Three fellows and 31 members have been dropped from the mailing list for non-payment of dues, so that there is a loss of 3 fellows and a gain of 17 members for the year. No deaths have been reported during the year. In addition to the 340 fellows and members, there are 185 subscribers, a gain of 22 for the year. A total of 525 paid copies of the Journal are mailed monthly, an increase of 46 over last year. Actually, during the past year, 3 fellows, 50 members, and 22 subscribers or a total of 75 were added, and the net gain of 46 is larger than last year.

Respectfully submitted,
FRANK R. VAN HORN, *Secretary.*

REPORT OF THE TREASURER FOR 1928

The Treasurer read his report, and on motion it was accepted and ordered filed. On motion an auditing committee composed of non-members of the Council was appointed by the President. This committee consisted of A. C. Hawkins, Harry Berman and R. B. Gage, and later reported to the Secretary that they found the books of the Treasurer correct. The Treasurer's report follows:

To the Council of the Mineralogical Society of America: Your treasurer herewith submits his annual report for the year ending November 30, 1928:

RECEIPTS

Cash on hand December 1, 1927	$3,210.61	
Dues and subscriptions	1,535.27	
Advertisements	232.15	
Sale of back numbers	984.28	
Interest on Endowment and bank deposits	2,441.54	
Miscellaneous	37.58	
		$8,441.43

DISBURSEMENTS

Printing and distribution of the Journal	$3,091.39	
To the Editor, Secretary and Treasurer	700.00	
Printing of separates	110.55	
Stationery and postage	39.90	
Miscellaneous	52.25	
2 $1000 Bonds, Trenton Mortgage & Title Guarantee Co. (5½%, due 1937)	2,022.92	
	$6,017.01	
BALANCE in Princeton Bank & Trust Co., Nov. 30, 1928	2,424.42	$8,441.43

The Endowment consists of 45 one thousand dollar bonds of the City and County of Honolulu	$45,000.00
4 Liberty Bonds of $100 each, 4th 4¼%	400.00
3 $100 bonds of the Great Northern R.R. 5½ Gold	300.00
2 $1000 bonds, Trenton Mortgage & Title Guarantee Co., 5½%, due 1937	2,000.00
	$47,700.00

Respectfully submitted,
ALEXANDER H. PHILLIPS, *Treasurer.*

REPORT OF THE EDITOR FOR 1928

The report was read by the Editor, and on motion it was accepted and ordered filed.

To the Council of the Mineralogical Society of America: A critical survey of the status of the Journal for the year that is now drawing to a close reveals both pleasant and unpleasant features. In a number of respects 1928 has been the most satisfactory year in the history of the Society. It is gratifying to report that the steady growth, in recent years, in the size of the *Mineralogist* has culminated in the establishment of a new record of 600 pages for the current volume. This is equivalent to an average of 50 pages for each of the 12 numbers. This figure represents an increase of 150 pages over the previous high mark of a year ago.

There are two factors that, no doubt, have contributed to the attainment of this new goal. One large special issue of 170 pages, containing 14 articles, has of course greatly assisted in producing this high total. The unsolicited laudatory letters received, from home and abroad, upon the appearance of each special number clearly indicates that this policy should be continued and encouraged. It is hoped that the publication of at least one special issue each year might become a regular feature of the Journal, but thus far only two institutions have availed themselves of the opportunity to take over an entire number.

It is also believed that the change in policy whereby contributors are granted 50 reprints has had the effect of attracting a number of articles that otherwise might have been sent elsewhere. This policy which became effective with the March issue has proved so satisfactory to our contributors that it is safe to say that it will become a fixed policy for the future. This innovation has not been a heavy burden financially as the extra cost to the Society for these reprints for the nine months period has averaged about $20 per issue.

Incidentally it may be stated that the reprint business is a sensitive subject with all publishers. The volume of such business after all is small and unprofitable, but they regard this phase of their work as a necessary evil and attempt to establish rates based on actual cost. After a lengthy correspondence an agreement has been reached with our publishers (but not without a struggle) whereby the rates now in force will continue for another year.

Two years ago the Council authorized an expenditure of $850 to republish the first five volumes of the Journal. It seemed at that time that the demand for these early numbers, and for subsequent issues which the early volumes would make available, justified the venture. The sale of back numbers within the last two years has demonstrated the wisdom of this undertaking. Professor Phillips's report a year ago indicated a sale of $500 and this year that amount has been doubled. In less than two years the total cost of reprinting has been met while more than half of the supply of these volumes are still on hand for future calls.

While this brief review covers some of the more encouraging aspects there are also a number of features of a less pleasant nature that should be mentioned in an honest appraisal of the year's work. The dues and subscriptions received during 1928 show a decrease over the same period a year ago. A slight increase in revenue from this source, rather than a decrease, might very reasonably be considered a normal expectancy. Surely the interest in mineralogy is not on the decline and the price of the Journal could hardly be considered excessive as it is being sent to the members at less than actual cost.

The summer and fall issues are still a matter of grave concern to the Editor. In the past publication during the summer has only been made possible by drawing upon manuscripts received in the spring and purposely held back to tide over this lean period. But this procedure has the objectionable feature of causing undue delay and most authors are quite insistent (and rightly so) upon prompt appearance. To conform to their wishes in all instances would, however, result in the suspension of the Journal during several months of each year. Perhaps that will be the ultimate solution but I am still hopeful that when the seriousness of the situation is fully realized sufficient material will become available to insure twelve issues without holding back certain articles six months as was the case this year.

In attempting an analysis of the Journal we find that 42 individuals have contributed one or more of the 57 leading articles that have appeared in the current volume. These articles represented contributions from 26 different Universities and research Bureaus. It is gratifying to note that nine manuscripts were received from outside of the States, one each from Peru, Germany and Australia, and six from Canada.

Of the 57 leading articles, 6 recorded for the first time descriptions of new mineral species; 7 described famous mineral localities; 23 called attention to new data on established species and 21 consisted of addresses, memorials and articles of a miscellaneous character.

The series of mineral locality articles, which was started several years ago, should appeal especially to our friends the collectors and will be continued from time to time as suitable material becomes available. I am sure all of you will be delighted to know that the January issue will include a paper by Professor Palache on a *Paragenetic classification of the minerals of Franklin, New Jersey*, while in the February number the same author will compare the ore deposits of Långban, Sweden, with those of Franklin.

The 57 leading articles of the present year occupied 526 pages or 88.7% of the total space, while 15 book reviews, 24 reports of proceedings of societies, 48 abstracted accounts of new mineral names and 43 other items of general interest, including short articles and brief discussions, filled the remaining 67 pages or 11.3% of the space of the Journal.

In conclusion may I leave with you these two suggestions and ask your assistance in seeing them realized; first, the desirability of substantially increasing from year to year the membership of the Society in order that the interest in the subject of mineralogy might be adequately maintained; and second, the need of more material for the Journal if the growth enjoyed in the past is to be continued.

The concluding table of contents summarizes the distribution of subject matter in volume 13.

Distribution of Subject Matter in Volume 13

Subjects		*Articles*	*Pages*	*Per Cent of total*
Original articles				
New mineral species	6			
Mineral locality articles	7			
New data on established species	23			
Memorials, addresses, etc.	21			
	—	57	526½	88.7
Proceedings of societies		24	27	11.3
Notes and news		43	15½	
Book reviews		15	9½	
Abstracted accounts of new mineral names		48	14½	
Total of text		187	593	100.0
Illustrations		179		
Covers, advertisements, index			94	
Total			687	

Respectfully submitted,
Walter F. Hunt, *Editor.*

REPORT OF THE COMMITTEE ON NOMENCLATURE AND CLASSIFICATION OF MINERALS

Dr. H. S. Washington, Chairman, reported that the members of the committee residing in Washington had had one meeting, and asked that the committee be discharged. A motion to this effect was carried. Dr. W. T. Schaller then moved that the President appoint a special committee of three, of whom not more than one has served on the Committee on Nomenclature, to reread all of the reports of that committee and abstract therefrom the most pertinent and important suggestions and submit them, in condensed form, at the next meeting, with a request that such a condensed report be printed in *The American Mineralogist.* This motion was seconded and after some discussion was carried. The President appointed W. T. Schaller, C. S. Ross, and E. T. Wherry.

REPORT OF THE COMMITTEE ON PRESERVATION OF TYPE MINERALOGICAL MATERIAL

Dr. W. T. Schaller read the second and final report signed by all the members of the committee and asked that the committee be discharged. A motion to this effect was carried. The report of the committee follows:

Second Report of Committee on Preservation of Type Mineralogical Material

The Committee on Preservation of Type Mineralogical Material has been considering the possibility of devising a scheme for the permanent preservation of all type mineralogical material, especially new species, so that it may be preserved for future comparison and reference. It has not been possible to select a single institution for such a repository as many institutions consider the original material described by their members as part of their most highly prized possessions,—and rightly so. Other institutions, however, may feel that a designated repository may be better suited for the permanent preservation of type material than their own and may be willing to send it, or part of it, to a duly designated place, for permanent preservation.

It is not practical to designate, officially, one or two repositories for such type material, but the Committee recommends that all members residing in the United States be strongly urged, whenever such a course is feasible, to deposit their type material (holotype) or part of the type collection (paratype) in the U. S. National Museum at Washington, and that those members residing in Canada select one or more places in Canada where such type material can be preserved.

The Committee also recommends that all authors of mineralogical papers, and especially those describing new minerals or giving new facts, be urged to state in their paper the disposition of the type material. If entirely consumed (as it never should be), or if any of the material be sent to any repository, a statement to that effect should be given.

W. T. Schaller, *Chairman*
A. N. Winchell
A. L. Parsons
H. P. Whitlock
W. F. Foshag

REPORT OF REPRESENTATIVE ON THE NATIONAL RESEARCH COUNCIL

The representative of the Society, Dr. W. T. Schaller, gave a summary of the work attempted by the National Research Council and some of its committees during the past year.

NEW BUSINESS

Dr. T. L. Walker mentioned the possibility of a mineralogical section at the International Geological Congress to be held July 29, 1929 at Pretoria, South Africa, but stated that he had heard nothing definite about such a section.

PRESENTATION OF PAPERS

At 2:45 P.M., there being no further business, the Society proceeded to the reading of scientific papers. The papers presented with short abstracts follow:

Arthur L. Parsons: *The Determination of the Crystallographic Constants in Crystals of the Triclinic System.* The linear and polar constants are calculated directly and independently from two-circle measurements with the exception of γ which is determined from the five known angles. Average values are obtained for α, β, γ, c/a, c/b, p_0^1, q_0^1, ϕ_0 and ρ_0. The assigning of Weiss and Miller symbols is shown graphically.

W. T. Schaller: *Crystallography of the Quartz Pseudomorphs from Paterson, New Jersey.* Angular measurements of the faces of the quartz pseudomorphs from Paterson show identity with the angles of glauberite.

H. P. Whitlock: *Some Devices and Models for the Demonstration of Symmetry.* These devises and models are of several types. (1) There is a series of stereograms, that, beginning with close piled particles, show in three dimensional graphs the symmetry of several atomic group types. (2) There is a series of symmetry-targets which rotate designs drawn in flat symmetry, and also three dimensional portions of crystal models. (3) There is an adaptation of kindergarten blocks to the building of symmetrical designs in two-dimensional patterns.

A. F. Rogers: *A Study of the Crystal Systems.* Crystal systems are not fundamental in the sense that crystal classes are; they are, however, useful and convenient. Contrary to general opinion, crystal systems are not based primarily upon the kinds of axes of reference used but upon the properties that certain classes have in common.

Since systems are not fundamental, all ideas and terms involving holohedrism and merohedrism should be discarded.

Six systems are used instead of seven; the hexagonal system is divided into two sub-systems, the rhombohedral sub-system with five classes and the hexagonal sub-system with seven classes.

* * * *

At 3:55 P.M., the Society adjourned to the Duplex Assembly Room of the Museum to attend a joint session with the Geological Society of America at 4 P.M. before which the presidential address of Professor Esper S. Larsen on "*The Temperatures of Magmas*" was given. This paper is published in full in this number. Following this address with E. S. Larsen presiding, papers of the Geological Society of a mineralogical and petrographical nature were presented. The joint session adjourned at 6 P.M.

On Friday, December 28, at 9:12 A.M., President Larsen called the second session of the Society to order in the New York Academy Room of the Museum, and the reading of papers proceeded according to program.

A. F. Rogers: *Polysynthetic Twinning in Dolomite.* The most common type of twinning in dolomite is polysynthetic with $(02\bar{2}1)$ as twinning plane. The twinning lamellae appear as "striations" parallel to the short, long, or both diagonals of the rhombs of the cleavage surfaces. Especially good examples are found at Tilly Foster, New York, Providence, R. I., and Charlemont, Mass. The Tilly Foster dolomite shows parting parallel to $(02\bar{2}1)$, which is due to twinning.

Polysynthetic twinning with $(02\bar{2}1)$ as twinning plane is very common in the dolomite of metamorphic rocks and affords a convenient method of distinguishing dolomite from calcite.

E. Posnjak and G. Tunell: *The Optical and Geometrical Properties of the Basic and Normal Cupric Sulfates and Cupric Oxide, Tenorite.* Data for the indices of refraction, pleochroism, optical orientation, geometrical crystallographic elements and the x-ray diffraction patterns of the basic and normal cupric sulfates and cupric oxide were obtained as part of an investigation of the system, $CuO-SO_3-H_2O$. Definite compounds in separate single crystals were synthesized, several of which are well known to mineralogists. Solid solution which had been reported was proved not to occur.

Lewis S. Ramsdell: *An X-ray Study of the Domeykite Group.* A correlation of the members of the domeykite group with the Cu—As constitution diagram. This paper will be printed in an early issue of this Journal.

John W. Gruner: *On the Structure of Boracite.* Large dodecahedra of boracite each consisting of twelve orthorhombic sectors were cut into sections for oscillation spectrograms in the seven major crystallographic directions. The unit cell of boracite is base centered orthorhombic, and contains eight molecules of $Mg_6Cl_2B_{14}O_{26}$. Its dimensions are $a_0=b_0=16.97$ A°. $c_0=12.00$ A°. The space group is probably C^{11}_{2v}, though C^{12}_{2v} could not be eliminated as a possibility.

Ernest E. Fairbanks: *Photo-luminescence of Minerals.* The fluorescence of minerals obtained by excitation with ultra-violet light from which practically all visible light has been filtered out, is a fascinating study. Fluorescence has been found useful to the mineralogist in a number of ways. A brief review of some of these applications is given including the identification of gems and minerals, and the detection of minute quantities of certain activating materials. The transmission of filters and of the quartz mercury lamp is described.

A. F. Rogers: *Mineral Determination in Crushed Fragments with the Polarizing Microscope.* The value of the polarizing or petrographic microscope in determining minerals by means of crushed fragments is emphasized. It has been found that on account of cleavage and structure the shape of crushed fragments is highly characteristic of many minerals.

A convenient method of arranging and using index liquids in dichotomous order is described.

C. E. Miller: *The Interfacial Tension of Crystal Faces.* A study of the interfacial tension of crystal faces, and its effect upon liquids of known surface tension. Preliminary results, purely qualitative, showing that real differences in the interfacial tension for various minerals and crystal forms do exist, were obtained by Quincke's "flat liquid drop" method, the relative amount of "wetting" being noted. Quantitative values seem to be impossible on account of the many disturbing factors that tend to influence the results and for which compensation must be made; room vibrations, temperature changes, crystal face variations, and possible chemical affinity of the minerals for the liquids used. The following minerals have been studied: celestite, barite, pyrite, sulphur, spinel, franklinite, fluorite, calcite, stibnite, gypsum, quartz, tourmaline, and the micas.

W. T. Schaller: *Ending of Chemical Adjectives in Isomorphous Minerals.* Isomorphous replacement of an element by a minor and variable other element should be designated by a chemical adjective which should have a uniform ending. Several such endings are considered, objections noted, and suggestions made for a uniform procedure.

W. T. Schaller: *The Ludwigite Group.* The end members of the ludwigite series are: ludwigite $4\ MgO.\ B_2O_3.\ Fe_2O_3$, and vonsenite $4\ FeO.\ B_2O_3.\ Fe_2O_3$. Both are orthorhombic with similar angles. The two end members are isomorphous. The names ferroludwigite and magnesioludwigite are to be discarded.

L. H. Bauer and Harry Berman: *On a New Basic Sulphate and Two Borates of Magnesium from Sterling Hill and Franklin, New Jersey.* A basic sulphate from Sterling Hill is associated chiefly with pyrochroite, calcite and with a new borate. It occurs in two varieties differing slightly in the amount of the bases present and in the formulae assigned: Mooreite $7R(OH)_2.RSO_4.4H_2O$; δ–Mooreite $6R(OH)_2.RSO_4.4H_2O$, where R = Mg, Zn, Mn.

Both are monoclinic and in tabular crystals. The name mooreite is proposed for this mineral in honor of Gideon E. Moore, an early investigator of Franklin minerals.

The borate associated with mooreite, and another borate from Franklin, associated with zincite and smithsonite, are probably new species closely related to fluoborite.

L. H. Bauer and Harry Berman: *A New Basic Carbonate of Managanese and Zinc from Franklin, New Jersey.* In a single specimen from Franklin, N. J., bluish white needles of the new mineral are associated with sussexite, pyrochroite and calcite. These needles are monoclinic and have the following composition: $2RCO_3.5R\ (OH)_2$, where R is chiefly manganese and zinc.

The name loseyite is proposed for this mineral in honor of S. R. Losey, a former resident of Franklin, active in the preservation of the local minerals.

W. F. Foshag: *Carminite from Mexico and Colorado.* Carminite, a very rare arsenate of lead and iron, was first described as occurring sparingly in the Luise limonite mine at Horhausen, Germany. Later small amounts have been found at Cornwall. More recently this mineral has also been found at the Ojuela Mine, Mapimi, Durango, Mexico, and in Colorado. Its chemical composition is shown to be $PbO.Fe_2O_3.As_2O_5.H_2O$. The crystallization orthorhombic.

A. F. Rogers: *Periclase from Crestmore, near Riverside, California.* To the list of about 70 minerals found in the contact-metamorphic zone, berween granodiorite and limestone at Crestmore, California, another must be added, namely periclase or isometric magnesium oxide. The periclase occurs as cores within some of the brucite of the calcite-brucite rock or predazzite. The brucite has been formed by the hydration of the periclase probably by hydrothermal alteration. The associated minerals are chondrodite and spinel.

This is the second occurrence of periclase in the United States and there are at least three other occurrences of predazzite.

M. N. Short and E. V. Shannon: *Violarite, a Rare Nickel Mineral.* The formula for violarite has been determined to be $(Ni, Fe)_3\ S_4$ on carefully selected material from Sudbury, Ontario, and from the Friday mine, San Diego County, California. Violarite is similar in composition and physical properties to linnaeite, Co_3S_4.

C. B. Slawson: *Quantitative Optical Determination of Potassium and Sodium Chlorides.* When potassium and sodium chlorides are fused together mixed crystals with the composition xKCl.yNaCl are formed. These mixed crystals may be identified by the determination of the index of refraction and the relative percentages of potassium and sodium may be estimated to within 2%. The mixed crystals are not stable at ordinary temperatures.

E. S. Larsen and W. T. Schaller: *Serendibite from Warren County, New York.* This second locality of serendibite is along the contact of Grenville limestone and granite gneiss. Associated minerals are typical contact-metamorphic ones:—phlogopite, diopside, tremolite, spinel, etc. An unknown silica-free mineral with optical constants like diopside is present. The serendibite is granular massive without crystal faces. Optically +, 2V near 90°, $\alpha=1.701$, $\beta=1.704$, $\gamma=1.706$. Prominent polysynthetic twinning.

Chemical analysis yields formula: $4SiO_2.3Al_2O_3.2CaO.4MgO.B_2O_3$.

A. R. Crook: *An Illinois Record Copper Erratic.* In various places in Illinois, chiefly in association with Illinoian and Wisconsin drift, numerous pieces of drift copper have been found.

A table is given showing weight, dimensions, name of finder, locality where discovered and where preserved, of all specimens known to the writer to have been found in drift in Illinois.

They range in weight from a fraction of an ounce to 1606 pounds. As far as known, the latter is the largest ever found in Illinois. It is an irregular oblong mass, 51 in. long, 34.5 in. high and 6 in. thick. There are a few projections remaining after its 500 mile trip from the Lake Superior region. It was discovered by a young farmer on his farm eight miles southwest of Canton. On the flat sides glacial striae are much in evidence and in the hollows are dendritic and aborescent patches. Calcite crystals appear in places but no silver is discernable. It is now in the State Museum.

Levi S. Brown (Introduced by Frank R. Van Horn): *Notes on the Appearance of Tourmaline in Sediments.* Correlation in Mid-Continent sediments, Permian and Pennsylvanian, is largely on the basis of petrography alone. Tourmaline is always present, but in exceptionally varied appearance. Hence, in routine examination prompt identification is sometimes difficult. Some of the characters of the tourmaline, as here exhibited, are described in some detail, in this paper.

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The last paper was finished at 1 P. M., after which it was moved that the thanks of the Society be extended to the local committee, and to the authorities of the American Museum of Natural History and Columbia University for their kindness and hospitality. This was seconded and unanimously adopted after which the Society adjourned to meet at 2 P. M. in joint session with the Society of Economic Geologists.

The joint session with the Society of Economic Geologists was called to order at 2:15 P. M. by President Larsen. Later in the afternoon, President W. H. Emmons of the Economic Geologists was in the chair. Short abstracts of papers presented by members of the Mineralogical Society follow:

Samuel G. Gordon: *The Passing of the French Creek Mines.* After years of idleness the French Creek Mines were reopened in 1915. On October 13, 1928, the mine was abandoned as exhausted. In that period 850,000 tons of iron ore was mined. The mine was noted as a local source of fine specimens of pyrite, chalcopyrite, magnetite, apophyllite, calcite, and many other minerals.

Samuel G. Gordon: *Remarks on Llallagua Phosphates.* Apatite and wavellite are very abundant minerals in the Llallagua tin mines. Vivianite is not uncommon.

Vauxite, paravauxite, and metavauxite have frequently been found. Monazite and xenotine have recently been identified as occurring rarely. A new analysis shows the composition of wavellite to be $2Al_2O_3.2P_2O_5.2Al(OH,F)_3.10H_2O$. A variety of allophane containing 7.97% P_2O_5 is called phosphate allophane.

George L. English: *Diamonds and Diamond Mines in South Africa.*

(a) The Diamond:
  Its Form and Physical Properties.
  Its Genesis.
(b) Occurrences of Diamonds in South Africa.
  New Discoveries.
(c) From the dark mine to the glittering ball room.

Charles Palache: *Paragenetic Classification of the Minerals of Franklin, New Jersey.* A list is given of 137 species of minerals which are found in the region near Franklin, N. J. It is shown that these may be classified genetically into five groups of varying importance. Of the whole number of species, 111 are found in the zinc ore-bodies and 98 in these only; 13 are found in granite pegmatites; 18 in iron ores of pegmatic origin; 26 in the Pre-Cambrian limestone and 5 in the Paleozoic limestone. These five paragenetic groups are described, those of less importance first and then the main group of the zinc-ore minerals. A paragenetic table for this group shows four main subdivisions viz:—(1) Primary Ores: (2) Pegmatite Contact Minerals, (a) Skarns and recrystallization Products; (b)Pneumatolytic Products: (3) Hydrothermal Vein Minerals: (4) Surface Oxidation Products.

Each of these groups is described with examples of characteristic mineral associations.

The origin of the zinc ores is discussed.

Charles Palache: *Comparison of the Ore Deposits of Långban, Sweden, with those of Franklin, New Jersey.* The Långban ores are briefly described by a quotation from a review of Magnusson's article together with a reprint of his paragenetic table. It is shown that not more than 16 of the very numerous minerals peculiar to this deposit are also found at Franklin and that these are not of great importance. The only common factor in the genetic histories of the two deposits is the formation of silicate skarns, at Långban caused by regional rise of temperature, at Franklin produced locally by intrusion of granite pegmatites.

A. A. Pegau: *The Rutherford Mines, Amelia County, Virginia.* This paper deals with the geology and mineralogy of the pegmatites on which the Rutherford Mines are located. A recent survey has shown that the rare minerals, reported from the Amelia locality, are for the most part confined to these dikes. They are located in the Piedmont and are enclosed by a biotite gneiss of monzonitic composition. The texture of the pegmatite is determined by the chief mineral albite, which occurs as beautifully crystallized, platy, reticulated, fragile masses in the interstices of which occur many rare and unusual minerals. The texture of the near-by dikes is prevailingly graphic. A total of thirty-three mineral species have been reported from this deposit, while only a half dozen or so have been found in the other deposits in this area. This unusual texture and composition seems best explained as resulting from a replacement process in which potash feldspar has been replaced by soda feldspar, accompanied by the introduction of the rare minerals.

A. C. Hawkins: *New and Unusual New Jersey Mineral Occurrences.* Covellite has been discovered at Schuyler Mine, Arlington, and is new to New Jersey. Natrolite from Millington in fine though small terminated crystals shows twinning on one of the pinacoids, probably *a*, like scolecite. Stilbite and heulandite occur in a very scoriaceous basalt at Summit in very good specimens. This is a little known locality.

C. S. Ross and E. V. Shannon: *The Manganese Minerals of a Hydrothermal Vein near Sparta, North Carolina.* A hydrothermal vein located about 3 miles northeast of Sparta, North Carolina, and near the North Carolina-Virginia State line, contains an interesting group of minerals. The vein has evidently been formed by hydrothermal processes and contains a rather large group of hypogene silicates, carbonates and oxides. The most interesting of these are tephroite, a new manganese-aluminum spinel, rhodonite, manganese bearing carbonate, and two types of garnet. Associated with this are magnetite amphiboles and a few less abundant minerals. A subsequent period of mineralization has introduced quartz and sulphides.

W. T. Schaller: *Halite-anhydrite Intergrowths from Texas.* Intergrowths of large crystal units of halite and fine-grained anhydrite are present in some of the cores from the potash field of west Texas. The halite occurs in units that are six-sided in cross section. The shape of the units suggests that they may be pseudomorphous after a pre-existent unknown mineral.

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The joint session adjourned at 6 P.M. During the afternoon 9 papers were read by members of the Mineralogical Society and 4 papers were presented by members of the Society of Economic Geologists.

During the sessions of the Society a total of 32 scientific papers were presented. 41 fellows, 51 members and 16 guests registered at the meetings, making a total of 108, which exceeds all previous records of attendance. The following registered at the meetings:

H. L. Alling, Miss O. F. Apple, H. W. Arndt, R. Ballintine, H. M. Bannerman, Miss Florence Bascom, L. H. Bauer, W. S. Bayley, H. Berman, M. Billings, H. R. Blank, P. Bosch, N. L. Bowen, L. S. Brown, E. L. Bruce, A. F. Buddington, W. S. Burbank, J. D. Burfoot, Jr., B. T. Butler, E. Callaghan, Miss G. M. Carhart, Ian Campbell, R. J. Colony, C. S. Corbett, A. R. Crook, N. C. Dale, Miss R. A. Doggett, C. G. Doll, E. E. Fairbanks, C. R. Fettke, W. F. Foshag, R. B. Gage, E. K. Gedney, J. E. Gill, J. Gilluly, F. A. Gonyer, S. Gordon, C. K. Graeber, R. P. D. Graham, W. A. P. Graham, F. L. Grout, J. W. Gruner, A. C. Hawkins, F. L. Hess, D. F. Hewett, T. M. Hills, C. W. Hoadley, A. P. Honess, W. V. Howard, W. F. Hunt, W. A. Johnston, Jr., P. F. Kerr, J. D. Kraus, E. H. Kraus, G. F. Kunz, A. C. Lane, E. S. Larsen, J. V. Lewis, L. McI. Luquer, J. G. Manchester, J. H. C. Martens, E. B. Mathews, E. A. Maynard, B. L. Miller, C. E. Miller, R. B. Miller, E. S. Moore, J. P. Morton, W. M. Myers, G. W. H. Norman, F. M. Oldach, Charles Palache, A. L. Parsons, M. A. Peacock, A. A. Pegau, O. F. Pfordte, A. H. Phillips, R. S. Poor, H. A. Powers, L. S. Ramsdell, H. Ries, A. F. Rogers, C. S. Ross, J. J. Runner, E. Sampsom, W. T. Schaller, J. F. Schairer, H. Schneider, F. C. Schrader, M. W. Senstius, B. M. Shaub, M. N. Short, C. B. Slawson, Miss

I. F. Smith, C. H. Stockwell, M. H. Stow, J. L. Stuckey, S. Taber, E. Thomson, D. W. Trainer, Jr., G. Tunell, F. R. Van Horn, T. L. Walker, H. S. Washington, L. G. Westgate, E. P. Wheeler, 2nd, E. T. Wherry, and H. P. Whitlock.

LIST OF FORMER OFFICERS AND MEETINGS, WITH DATES

By recommendation of the Council, a complete list of past officers is printed in the proceedings of the annual meeting of the Society.

	Presidents		Vice-Presidents
1920	Edward H. Kraus	1920	Thomas L. Walker
1921	Charles Palache	1921	Waldemar T. Schaller
1922	Thomas L. Walker	1922	Frederick A. Canfield
1923	Edgar T. Wherry	1923	George F. Kunz
1924	Henry S. Washington	1924	Washington A. Roebling
1925	Arthur S. Eakle	1925	Herbert P. Whitlock
1926	Waldemar T. Schaller	1926	George Vaux, Jr.
1927	Austin F. Rogers	1927	George L. English
1928	Esper S. Larsen	1928	Lazard Cahn

	Secretaries		Treasurers
1920–1922	Herbert P. Whitlock	1920–1923	Albert B. Peck
1923——	Frank R. Van Horn	1924——	Alexander H. Phillips

	Editors
1920–1921	Edgar T. Wherry
1922——	Walter F. Hunt

Councilors

1920. Arthur S. Eakle, Frank R. Van Horn, Fred E. Wright, Alexander H. Phillips.
1921 Frank R. Van Horn, Fred E. Wright, Alexander H. Phillips, Austin F. Rogers.
1922 Fred E. Wright, Alexander H. Phillips, Austin F. Rogers, Thomas L. Watson.
1923. Alexander H. Phillips, Austin F. Rogers, Thomas L. Watson, Esper S. Larsen.
1924 Austin F. Rogers, Thomas L. Watson, Esper S. Larsen, Arthur L. Parsons.
1925 Thomas L. Watson, Esper S. Larsen, Arthur L. Parsons, William F. Foshag.
1926 Esper S. Larsen, Arthur L. Parsons, William F. Foshag, William A. Tarr.
1927 Arthur L. Parsons, William F. Foshag, William A. Tarr, Alexander N. Winchell.
1928 William F. Foshag, William A Tarr, Alexander N. Winchell, Ellis Thomson.

	Annual Meeting Places
1920	Chicago, Illinois
1921	Amherst, Massachusetts
1922	Ann Arbor, Michigan
1923	Washington, D. C.
1924	Ithaca, New York
1925	New Haven, Connecticut
1926	Madison, Wisconsin
1927	Cleveland, Ohio
1928	New York, New York.

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Becke, Friedrich J., University of Vienna, Austria.
Brauns, Reinhard, University of Bonn, Germany.
Brögger, Waldemar C., University of Oslo, Norway.
Friedel, A., University of Strassburg, Strassburg, Alsace, France.
Goldschmidt, Victor, University of Heidelberg, Heidelberg, Germany.
Lacroix, A., Museum of Natural History, Paris, France.
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REVIEWS

MINERALOGY, AN INTRODUCTION TO THE STUDY OF MINERALS AND CRYSTALS. EDWARD H. KRAUS AND WALTER F. HUNT. Second edition, 604+ix pp., 766 illustrations. McGraw-Hill Book Co., Inc., *New York*, **1928**. Price $5.00.

This standard work on mineralogy, always excellent, has been rendered even more so in the present edition. It is notable for its clear print, few typographical errors, and its illustrations are for the most part excellent; altho a few of them might be made clearer, especially for the observation of beginning students. The photographs of wooden crystal models, always a desirable feature, have been retained and more added, together with more illustrations of mineral specimens, and a number of cuts of mining and mineral localities, which add much to the attractiveness and value of the book. Altogether there are 70 new cuts, which bring the total of the illustrations to 766. All of the chapters have been changed; the old ones have been expanded and brought up to date to include the new data accumulated during the eight years since the publication of the first edition; the classification of the minerals according to useful elements has been revised and modernized; new and complete chapters appear, dealing with crystal structure and X-ray analysis.

This book, written by university teachers of wide experience, breadth of view, and close contact with the rapid technical progress of the world today, is very desirable from the instructor's viewpoint. One could but wish that other authors of works on this and related subjects would revise their works with similar happy results.

ALFRED C. HAWKINS

PROCEEDINGS OF SOCIETIES

NEW YORK MINERALOGICAL CLUB

Minutes of the December Meeting

A regular monthly meeting of the New York Mineralogical Club, attended by thirty-five members, was held on the evening of December 19, 1928, with President Herbert P. Whitlock in the chair. By special invitation the meeting was held at the home of Dr. I. W. Drummond, a member of the Club, in New York City.

Messrs. Randolph Hawthorne and Albert E. Tarbox, both of Scarsdale, N. Y., were elected to membership.

Dr. I. W. Drummond addressed the Club on the subject of "*Jade and Amber*." After briefly discussing the occurrence and nature of these two materials, he exhibited and explained to the members his large collection of carved jade, amber objects and other minerals. Noteworthy features of the exhibit were a number of articles of "tomb jade" of archaeological interest, an unusual collection of Burmese amber, and a series of quartz "water geodes" (some in the matrix) from South America. In addition to these the members examined scores of beautiful objects of carved and polished jade, quartz, tourmaline, and beryl.

The meeting adjourned with a vote of thanks to Dr. Drummond in appreciation of his hospitality.

HORACE R. BLANK, *Secretary*

NEW YORK MINERALOGICAL CLUB

Minutes of the January Meeting

A regular monthly meeting of the New York Mineralogical Club was held at the American Museum of Natural History on the evening of January 16, 1929, with an attendance of 32 members. Second Vice-President George E. Ashby presided in the absence of the president.

Dr. Olaf Anderson, of Kearny, N. J., and Messrs. E. J. Gallagher, Newton Krumdieck, Lewis J. Warshow, and Mrs. Nellie Barrett Olson, all of New York City, were elected to membership.

The speaker of the evening was First Vice-President Frederick I. Allen, who addressed the Club on "*Chemistry in Mineral Determination*." After reviewing the advantages of chemical methods of determination, he described Fresenius's analytical classification of the elements as a basis for their separation and detection. Mr. Allen then demonstrated a number of qualitative tests for the detection of certain metals, including tin, gold, copper, iron, nickel, and titanium. Methods of bringing minerals into solution, bead tests, and the quantitative removal of certain elements such as silicon and aluminum were also touched upon.

The meeting adjourned with a vote of thanks to the speaker for his interesting talk and experiments.

HORACE R. BLANK, *Secretary*

NEWARK MINERALOGICAL SOCIETY

The Newark Mineralogical Society held its 103rd regular meeting on Sunday afternoon, January 6, 1929, in the library of the Newark Technical School, 367 High Street. Vice-President John A. Grenzig presided until the arrival of President Broadwell.

The notice sent out by Secretary Rodney B. Miller called for an old style meeting open to a general discussion of vital matters. Reports were presented by the various standing committees, suggestions offered relating to electing the President for a two-year period instead of annually, making the initiation fee one dollar and the dues two dollars, payable semi-annually.

A special meeting will be held at the Newark Museum on Sunday afternoon, January 20th, to inspect the Goetzke Gem Collection on the first floor and the Disbrow and other mineral collections on the third floor of the museum building.

The making of arrangements for this meeting was placed in the hands of the Publicity Committee. The same committee will take up with the Newark Public Library the purchasing of additional books, pamphlets and papers devoted to minerals and the study of mineralogy.

At the 104th regular meeting on February 3rd the members will have on exhibition recent acquisitions to their collections.

R. B. MILLER. *Secretary*